

Analysis of Geomechanical Behavior for the Drift Scale Test

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ANALYSIS OF GEOMECHANICAL BEHAVIOR FOR THE DRIFT SCALE TEST

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ABSTRACT

The Drift Scale Test (DST) now underway at Yucca Mountain has been simulated using a Drift Scale Distinct Element (DSDE) model. Simulated deformations show good agreement with field deformation measurements. Results indicate most fracture deformation is located above the crown of the Heated Drift. This work is part of the model validation effort for the DSDE model, which is used to assess thermal-mechanical effects on the hydrology of the rock mass surrounding a potential repository.

I. INTRODUCTION

The Yucca Mountain Site Characterization Project is conducting a drift scale heater test, known as the Drift Scale Test (DST), in an alcove of the Exploratory Studies Facility at Yucca Mountain, Nevada. The DST is a large-scale, long-term thermal test designed to investigate coupled thermal-mechanical-hydrological-chemical (TMHC) behavior in a fractured, welded tuff rock mass¹. The general layout of the DST is shown in Figure 1, along with the locations of several of the boreholes being used to monitor deformation during the test. Electric heaters are being used to heat a planar region of rock that is approximately 50 m long and 27 m wide for 4 years, followed by 4 years of cooling. Both in-drift and "wing" heaters are being used to heat the rock. The heating portion of the DST was started in December 1997, and the target drift wall temperature of 200°C was reached in summer 2000.

A drift-scale distinct element model (DSDE) is being used to analyze the geomechanical response of the rock mass forming the DST. The distinct element method was chosen to permit explicit modeling of fracture deformations. This is important because fracture deformation may alter thermal-hydrologic behavior in the

DST. Closing of fractures by thermal stresses may reduce fracture permeability, while shear deformation and normal mode opening of fractures could increase fracture permeability. This paper will describe the DSDE model and present preliminary results, including a comparison of simulated and observed deformations at selected locations within the test.

It is important to note that the DSDE model has been developed for analysis of thermal-mechanical (TM) effects on hydrological properties of the rock mass around emplacement drifts, and in the pillars between drifts in a potential geologic repository for radioactive waste. The analysis of the DST presented here represents part of the validation and confidence building effort for the DSDE model.

II. MODEL DESCRIPTION AND INPUTS

A DSDE model of the DST has been formulated using the 3DEC code² to provide for explicit modeling of fracture deformation. Locations and orientations of fractures in the rock mass being were determined by analysis of video logs for approximately 30 of the boreholes drilled into the DST block. The drift geometry and associated fracture planes used in the simulations are shown in the top and bottom parts of Figure 2, respectively. The thermal input to the simulation was based on the design input power for the test. Mechanical properties used in the simulation were taken from the Yucca Mountain site geotechnical rock properties data set³.

The DSDE model has been used to simulate the DST using both discontinuum and continuum representations of the rock mass. For the discontinuum simulation, the system of fractures and blocks shown in Figure 2 (bottom) was used. For the continuum simulation, these fractures were removed, and the rock mass was simulated

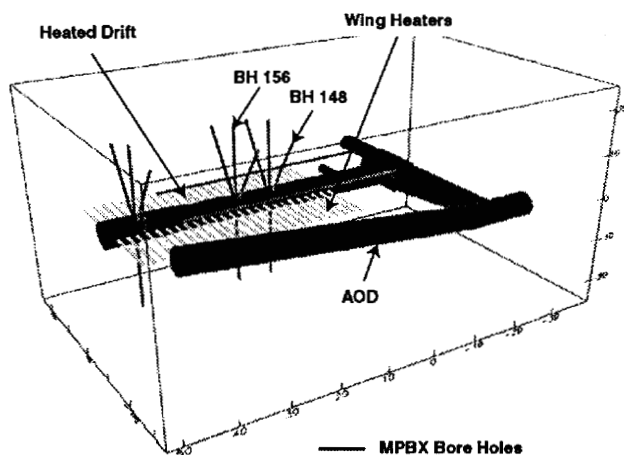


Figure 1. Layout of drifts and heaters in Drift Scale Test.

as a large, elastic block. The same temperature field was used for each simulation.

III. RESULTS

A. Simulation of Mine-By

Prior to the excavation of the Heated Drift (HD) three boreholes were drilled from the Access and Observation Drift (AOD) perpendicular to the planned location of the Heated Drift. These boreholes were instrumented with MPBX systems and deformation was recorded during the excavation of the Heated Drift. Simulation of the borehole response due to the excavation shows that at ambient temperature, the bulk and shear moduli of the rock are approximately 16 and 10 GPa, respectively.

B. Simulation of Heating Phase

The DSDE model has been used to simulate deformation behavior for several of the 12 boreholes that are collared in the Heated Drift and instrumented with MPBX instrumentation. Results indicate that for about half of the MPBX boreholes, the continuum and discontinuum formulations fit the observations equally well. These results indicate that a coefficient of thermal expansion of $4 \times 10^{-6} / ^\circ\text{C}$ is appropriate for this rock mass. This is consistent with values determined for the Single Heater Test, also conducted at Yucca Mountain⁴. Results also show that, for several of the boreholes drilled into the roof of the HD, the discontinuum predictions match the observations more closely than do the continuum predictions. An example is shown in Figure 3, which shows observed and predicted behavior for Borehole 156.

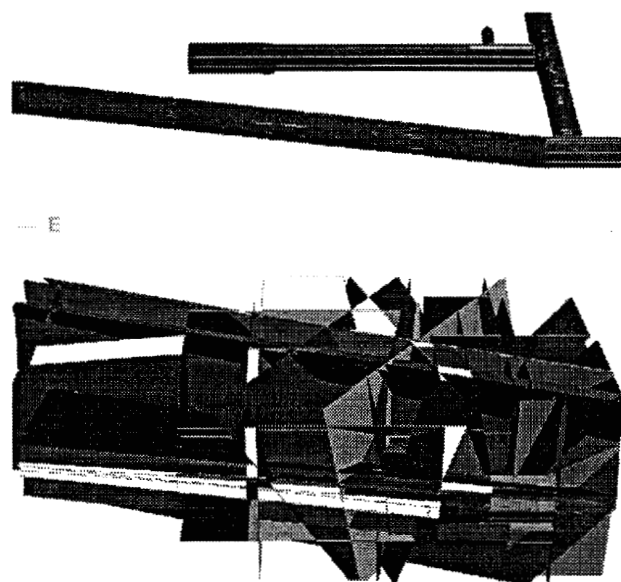


Figure 2. DSDE model formulation. Top figure shows simulated drifts, bottom figure shows the fractured block used to simulate the rock mass. The drifts are excavated within the fractured block.

This borehole is collared in the crown of the Heated Drift and extends vertically upward (see Figure 1). Figure 3 shows that both models underpredict the early deformation, but that the discontinuum model shows excellent agreement with observations after 450 days of heating, while the continuum model continues to underpredict the deformation. The underprediction at early times may be due to the thermal model used in 3DEC. Future work will include simulations in which temperature input is taken from TH models of the DST⁵. The increased deformation is attributed to opening and/or slip along a fracture in the discontinuum model.

C. Predicted Fracture Deformations

In addition to rock mass deformation estimates, 3DEC also provides predictions of normal and shear fracture displacements. Results indicate that normal mode opening primarily on two subvertical fractures above the Heated Drift, can be expected after 4 years of heating. This fracture opening is not shown after 8 years, indicating that normal mode opening may be reversible.

Predicted shear fracture deformations are also concentrated above the Heated Drift, but results indicate that the shear deformation may not be recoverable upon cooling. The predicted fracture deformations are

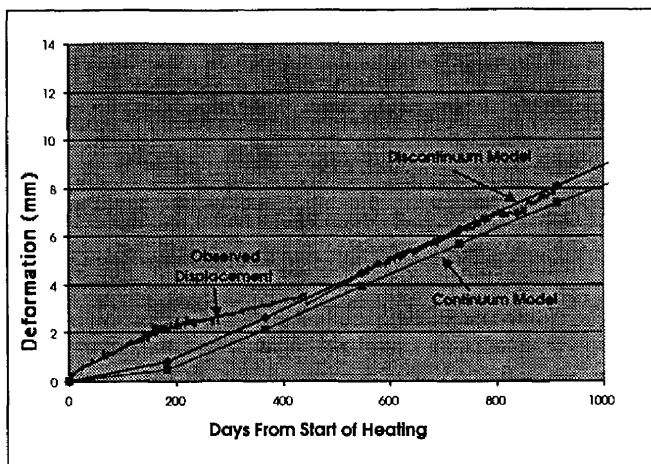


Figure 3. Predicted and observed deformation for anchor 4 in borehole 156 at the DST.

consistent with observed microseismic and acoustic emission activity, which indicate that rock movement is occurring along a few vertical fractures above the Heated Drift.

IV. CONCLUSIONS

We have simulated the Drift Scale Test at Yucca Mountain using a new drift scale distinct element (DSDE) model. The rock mass forming the DST was simulated both as a fractured rock mass and as a solid rock block. Results indicate that the predicted deformations agree quite well with in situ deformation measurements after the first year of heating. Predicted locations of fracture deformation also aid in the interpretation of observed microseismic activity.

Results provide guidance on values of the rock mass mechanical properties and on the nature and location of

deformations in the test. Simulations that included fractures match the observed deformation somewhat better than the simulations without fractures.

ACKNOWLEDGMENTS

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